'70's was from three to five mothers in every hundred, and sometimes childbed fever raged in epidemic form and killed at the rate of 20, 40 and even 55 mothers in every hundred!

Now, this most beautiful of all human relations has been made safe—mark my words—*made safe* by the researches, especially of Pasteur and his successors. *Bacteriology has won this splendid victory.* Within the last decade, series of 6,000, 7,000 and even over 8,000 cases have been reported *without the death of a single mother from infection.* Is not that a cause for a Te Deum?

But I must call a halt though I have not told even a small fraction of the fascinating story, of what, remember, I have been an enthusiastic living witness.

And what of the future? Have we any reason to expect other astonishing and beneficent discoveries? I answer with an unqualified affirmative. And it may well be still greater and still more beneficent discoveries.

With this word of cheer, I face the coming year or, if it so please God, the coming years, with a confidence which is enhanced by your wonderful tribute of affection.

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## THE RELATION OF MENDELISM AND THE MUTATION THEORY TO NATURAL SELECTION[1]

Two marked tendencies are evident in the history of any important theory after its publication.

First. The followers of the discoverer carry the theory too far and attempt too universal an application. This is manifestly true of Wallace and Weismann who out-Darwined Darwin in their claims for natural selection; of the followers of Mendel, such as Morgan and Pearl; and of many mutationists who make much greater claims for that theory than does De Vries himself.

Second. Each generation of biologists is so occupied with its own work and contemporary theories that it makes no real effort to understand preceding theories.

[1] Read before the American Society of Naturalists at Chicago, December 31, 1920.

This second tendency seems to me most marked in the attitude of present workers along genetic lines towards natural selection. They reveal an apparent lack of understanding of what Darwin really meant and of what he claimed; and when criticising that theory they are often engaged in the classic, but unprofitable, exercise of "fighting windmills."

In view of these facts I hope you will pardon me if I present in as few words as possible just what I believe to be the main factors which Darwin presented as resulting, in their actions and reactions, in natural selection. These factors are three in number:

First. *Heredity,* by which the progeny tend to resemble their parents more than they do other individuals of the same species.

Second. *Individual variation,* by which the progeny tend to depart from the parental type and sometimes from the specific type.

Third. *Geometrical ratio of increase,* by which each species tends to reproduce more individuals than can survive.

Each of these factors is practically axiomatic, so little is it open to argument.

No one doubts the *fact* of heredity, whether pangenesis, Weismannism or Mendelism be the correct expression of the mechanism involved. These do not affect the *fact* of heredity nor invalidate it as a factor in natural selection.

No one doubts the *fact* of variation; whether it is the "individual variation" of Darwin, the "fluctuating variety" or the "mutation" of De Vries. All that is necessary for Darwin's purpose is that there be heritable variations. That there are such things all parties agree and it matters little what you call them. They are adequate to act as a factor in the Darwinian scheme.

No one doubts the *fact* of geometrical ratio of increase. It is a proposition easily capable of mathematical demonstration, and that it *is* is sufficient for Darwin's purpose.

These three factors, then, are not debatable as facts, whatever their mechanism or causes.

A moment's reflection will show that geometrical ratio of increase is a *quantitative* factor, giving an abundance of individuals

from which to select; that individual variation is a *qualitative* factor, giving the differences which make a selection possible; and that heredity is a *conservative* factor, holding fast those characters which better fit the organism to its environment.

Now it seems to me that there is no possible outcome of the necessary action and interactions of these three factors that would not be a *selection* of some sort. Darwin thought it comparable in a large way to the selection by which the stock-breeder improves his herd, and therefore called it "natural selection," carefully guarding the phrase from misinterpretation from the teleological angle as well as from a too close parallelism between artificial and natural selection. And I believe no one has suggested a more acceptable term for the process of selection resulting from the interplay of natural laws.

Three outstanding theories have been advanced since the publication of the "Origin," each involving an advance in our knowledge of the mechanism of heredity on the one hand and of the origin of variations on the other.

Weismann's theory of the continuity and stability of the germplasm was of immense importance in its discussion of the mechanism of heredity, and his amphimixis gave a plausible explanation of the origin of variations. His results were almost universally regarded as confirming and greatly extending the scope of natural selection.

Mendel's theory regarding the purity of the gametes, their segregation in the sex cells, and the whole complex Mendelian mechanism so admirably described by Morgan; all of these, fascinating and important as they are, deal with the *mechanism* rather than the *fact* of heredity. In my opinion their acceptance or rejection does not affect the status of natural selection as a theory of organic evolution.

But it is the theory of mutation that has furnished most of the ammunition for the opponents of natural selection; and this in spite of the fact that De Vries, the originator of the mutation theory, expresses himself with great clarity as follows:

> My work claims to be in full accord with the principles laid down by Darwin and to give a thorough and sharp analysis to some of the ideas of variability, inheritance, selection and mutation which were necessarily vague in his time.

In 1904, when these words were published, there did seem to be a sharp distinction between the ideas of Darwin and those of De Vries. The former believed that natural selection acted upon many small variations and accumulated them until the differences were sufficient to constitute new species; while De Vries claimed that new species were formed by the sudden appearance by mutations of forms specifically distinct from the parents. That mutants *were* new species!

It seems evident that Darwin did not regard "saltatory evolution" as the common method, while De Vries did.

Darwin believed that individual, usually small, variations furnished the material on which selection acts; while De Vries thought that mutants, usually large variations, furnished the material. Both, however, believed thoroughly that natural selection was a *vera causa* of evolution.

But things have changed greatly since 1904. The work of Morgan, Castle, Jennings and a host of others has shown that many mutations are so small, from a phenotypic standpoint, that they are quantitatively no greater than the individual variations of Darwin; and that they are heritable in the mendelian way.

Castle produced a perfectly graded series of hooded rats which exhibits almost ideally the steps by which a new form might be produced by natural selection. He says:

> If artificial selection can, in the brief span of a man's lifetime, mould a character steadily in a particular direction, why may not natural selection in unlimited time also cause progressive evolution in directions useful to the organism?

Jennings says:

> Sufficiently thorough study shows that minute heritable variations—so minute as to represent practically continuous gradations—occur in many organisms: some reproducing from a single parent others by biparental reproduction. . . . It is *not* established that heritable changes must be sudden

large steps; while these may occur, minute heritable changes are more frequent. . . . Evolution according to the typical Darwinian scheme, through the occurrence of many small variations and their guidance by natural selection, is perfectly consistent with what experimental and paleontological studies show us; to me it appears more consistent with the data than does any other theory.

Many believers in mutation have been needlessly befuddled by the diverse meanings of "variations" as used by Darwin and De Vries. Darwin included in his "individual variations" both the "fluctuating varieties" and the "mutations" of De Vries. Phenotypically they can not even now be distinguished. De Vries himself candidly admits that this was Darwin's attitude, thus proving himself more clear-sighted than many of his followers. All that Darwin needed for his purpose was proof of variations that are heritable, and these are found in mutations, be they large or small.

Just as mendelism has to do with the *mechanism* and not the *fact* of heredity, so the mutation theory deals with the *nature* and not the *fact* of variations. Neither, in my opinion, has any implication that is antagonistic to the theory of natural selection.

The statement has often been made that natural selection "originates nothing" because it does not explain the origin of variations. I must confess to scant patience with this point of view. As well say that the sculptor does not make the statue because he does not manufacture the marble or his chisel; or that the worker in mosaic originates nothing because he does not make the bits of stone which he assembles in his design!

The material corresponding to the bits of stone in the mosaic is furnished by heredity and variation, and its quantity by geometrical ratio of increase. Natural selection acts in selecting and putting together this material in the formation of new species. Thus, in a true sense, it seems evident that something new has appeared—something that *is* but *was not*.

Another favorite figure, introduced I believe by De Vries, is "Natural selection acts only as a sieve" determining which forms shall be retained and which shall be discarded. This also seems to me to fall short of a complete statement of the truth. If the material subjected to the sifting process be regarded as changing with each generation by the addition of variations, or mutations if you prefer, some of which are favorable to a nicer adjustment of the species to its environment; the figure would be more nearly correct. To make it complete, however, the *mesh* of the sieve must change from generation to generation so that a quantitative variation which would be preserved in one generation would be discarded in a later one. But in this case natural selection would do more than a sieve could do. It would combine a number of favorable variations in the production of something new, a *new species!*

In conclusion it seems to me that we are justified in maintaining that Mendelism and the mutation theory, while forming the basis of the most brilliant and important advances in biological knowledge of the last half century, have neither weakened nor supplanted the Darwinian conception of the "Origin of species by means of Natural Selection."

C. C. NUTTING

## SCIENTIFIC EVENTS

### PROFESSOR CALMETTE ON A VACCINE FOR TUBERCULOSIS

THE Paris correspondent of the *London Times* reports that the *Petit Journal* publishes an interview with Professor Calmette, subdirector of the Pasteur Institute, which indicates that progress has been reached in the long struggle of the medical profession to find a cure for the ravages of tuberculosis. Professor Calmette was careful to tell his interviewer not to proclaim too widely that a cure has been found. "We are only at the dawn," he said. "The possibilities are immense, I can assure you, but we have still much work before us . . . in following the pathway which now lies open before us and which will lead us perhaps to a splendid realization of our hopes. Hope is now permissible."